LONG-TERM TRANSFER-LENGTH MEASUREMENTS ON PRETENSIONED CONCRETE RAIL ROAD TIES

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ABSTRACT

As a part of research study on concrete rail road ties, Sixty (60) concrete rail road ties were fabricated during January 2013 to measure 120 transfer length measurements through a mechanical gage (Whittemore gage). All these concrete ties were fabricated at a PCI certified concrete tie manufacturing plant with 15 different reinforcements that are widely used to manufacture concrete rail road ties all over the world. Variations of strain profiles for these reinforcements are measured after one year to evaluate the long term transfer length measurements. Strain profile measurements are also used to assess the creep in concrete at various cross-sections of concrete rail road ties with different reinforcements. These concrete ties are not subjected to any rail loads over this one year and are kept in two different environmental conditions, thus the primary variable affecting the creep in concrete is cross-sectional area of concrete. Strain growths at various cross-sections of a concrete tie evaluated and presented.

Keywords: *Prestress, Bond, Transfer Length, Railroad Ties, Indented Wire, Strand*

INTRODUCTION

Prestressed concrete railroad ties are becoming viable alternative for wooden ties due to various advantages and thereby rail road industry in the United States prefers concrete rail road ties over wooden ties. These preferential factors include; durability in severe weather conditions, efficiency to carry heavy railroad cars, longer service life[7], lower maintenance costs and environment friendly product.

However, it is essential to understand the factors that influence the performance of this engineered product (prestressed concrete rail road tie) in order to ensure the reliable performance though out its intended service life. This essential information will not only be useful to manufacture a better product but also helpful to understand the behavior of these concrete rail road ties for given circumstances.

Adequate structural performance of a concrete tie can be achieved by transferring prestressing force to the concrete member. In a pretensioned concrete member, full magnitude of effective prestress force can be transferred over certain length from the end of a concrete member and is referred to "transfer length"[2]. Researches[6, 9, 15, 16, 17, 18] have been conducted to evaluate the variations in transfer length with different parameters. These, factors include; concrete release strength, indent geometry of the prestress reinforcement, concrete mix proportions, presence of viscosity modifying admixture in concrete mix, consistency of concrete mix, water to cementitous of concrete mix, and time. Present paper focuses on transfer length growth in concrete railroad ties over one year period.

It is consensus opinion among the concrete tie manufacturing industry that indented reinforcement would improve the bond between the reinforcement and concrete and thereby, reducing transfer length. Previous researches had shown the improvement in bond performance due to the presence of indents on reinforcement[8, 11]. Hence, concrete tie manufacturers utilize indented wires or strands; whereas, due to its wide application, some tie manufacturers use smooth 7-wire strands.

In order to ensure reliable structural performance of a concrete tie throughout its service life, information about transfer length growth over a period of time is essential to obtain. Higher increase in transfer length growth may extend the transfer length of a tie to be beyond the application of rail road (typically 21-in. from the end of a tie) and further causes structural performance issues. Hence, for reliable structural performance of a tie, it is required to yield not only shorter transfer lengths but also lower increase in transfer lengths over a period of time. Although it known that transfer length will increase over time, the growth in transfer length for various types of indent geometries is essentially unknown.

As a part of this research study, sixty (60) concrete rail road ties were fabricated during January 2013 to measure 120 transfer length measurements through a mechanical gage (Whittemore gage). All these concrete ties were fabricated at a PCI certified concrete tie manufacturing plant with 15 different reinforcements that are widely used to manufacture concrete rail road ties all over the world. Fifteen (15) different reinforcements used for the portion of the study are shown in Figure 1 and Figure 2. These reinforcements included twelve 5.32-mm diameter wires (both indented and smooth), two 3/8-inch diameter 7-wire strands (both indented and smooth), and one 5/16-inch diameter 3-wire smooth strand.

Variations of strain profiles for these reinforcements are measured after one year to evaluate the long term transfer length measurements. Strain profile measurements are also used to assess the creep in concrete at various cross-sections of concrete rail road ties with different reinforcements. These concrete ties are not subjected to any rail loads over this one year and are kept in two different environmental conditions, thus the primary variable affecting the creep in concrete is cross-sectional area of concrete. Strain growths at various cross-sections of a concrete tie are compared and discussed.

A research team from Kansas State University (KSU) traveled to a PCI member plant for a period of three weeks to cast concrete ties with various reinforcements. Four ties were fabricated for each reinforcement type for a total of 60 ties which yielded 120 transfer lengths. Two ties for each reinforcement type were later stored at plant and the remaining two ties for each reinforcement type were shipped and stored at KSU laboratories. Long term transfer lengths are evaluated at both locations and are compared.

Figure 1 : Twelve different 5.32-mm diameter prestressing wires

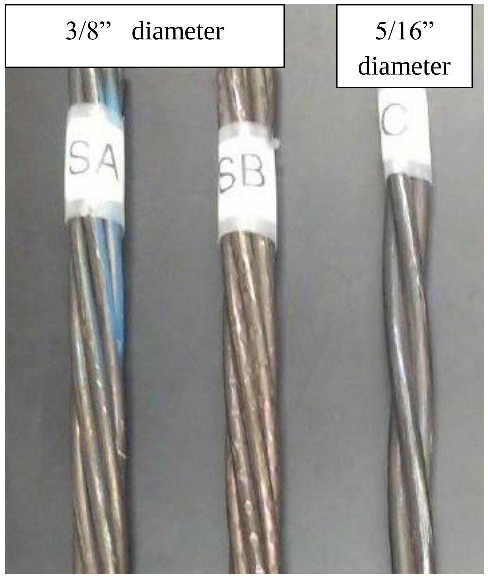


Figure 2 : Three different strands (from left to right: 7-wire smooth, 7-wire indented, and 3-wire smooth)

Concrete ties fabrication at PCI member plant

During the PCI member plant visit in January 2013, four concrete railroad ties were fabricated for each reinforcement type. Measures were taken to maintain these reinforcements in “as-received” condition. Same concrete mix design with water-cementitious ratio of 0.32 is used to fabricate all these concrete ties.

Total area of prestressing steel reinforcement and centroid of prestressing steel reinforcement for different sizes of reinforcement is maintained approximately the same. Prestressing force for each reinforcement type is verified through the center-hole load cell mounted on one of the tendons on live end. Various reinforcement patterns were used in the plant phase in order to provide the same steel area and centroid, and to be able to utilize the existing intermediate reinforcement supports (custom rebar chairs)[17].

Surface strains of concrete ties were calculated on as-cast top surface (actually the bottom side of the tie since the ties are cast upside-down) using traditional mechanical gage called Whittemore gage. All surface strain data was then analyzed by assuming a bilinear surface strain variation and the transfer length was determined[17].

Transfer Length measurements

During the casting process of concrete ties, brass points with small center hole were cast on as-cast top surface (actual bottom of the tie). These brass inserts were spaced longitudinally at a center-to-center spacing of one inch, for a distance of 42” longitudinally from the concrete tie ends. The entire process of mounting brass inserts into concrete tie is illustrated in Figure 3. The distance between these brass points was measured prior to prestress transfer and immediately after de-tensioning using a mechanical (Whittemore) strain gage with a precision of 0.0001 inches and an 8-inch gage length[17]. Later, distance these between these brass points was measured approximately after one year to evaluate long term transfer length. Concrete surface strain profiles were drawn from these measured concrete displacements at respective age (immediately after prestress transfer and one year after the cast). Strain measurement process though whittemore gage is shown in Figure 4.

Two sets of initial readings (prior to the prestress transfer) were always taken to minimize human error. A typical surface strain profile for concrete tie is shown in Figure 5. Transfer lengths were then determined by using both the 95% AMS Method [10] and the by the non-biased ZL Method [14]. A total of 120 immediate transfer lengths and 120 long term transfer lengths were determined on 60 concrete ties.

(a) Brass inserts mounted on steel bar at one inch spacing

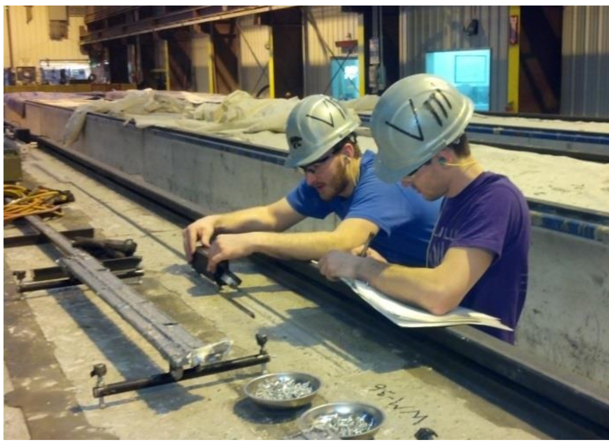
(b) Placing steel bar with brass inserts on the concrete cast surface

(c) Removal of steel bar from hardened concrete

(d) Concrete surface with brass inserts

Figure 3: Process of brass inserts insertion into concrete tie

(a) 8-inch gage whittemore gage used for strain measurements



(b) Distance measurement through whittemore gage prior to detensioning

(c) Distance measurement through whittemore gage after detensioning

Figure 4: Process of strain measurements through whittemore gage

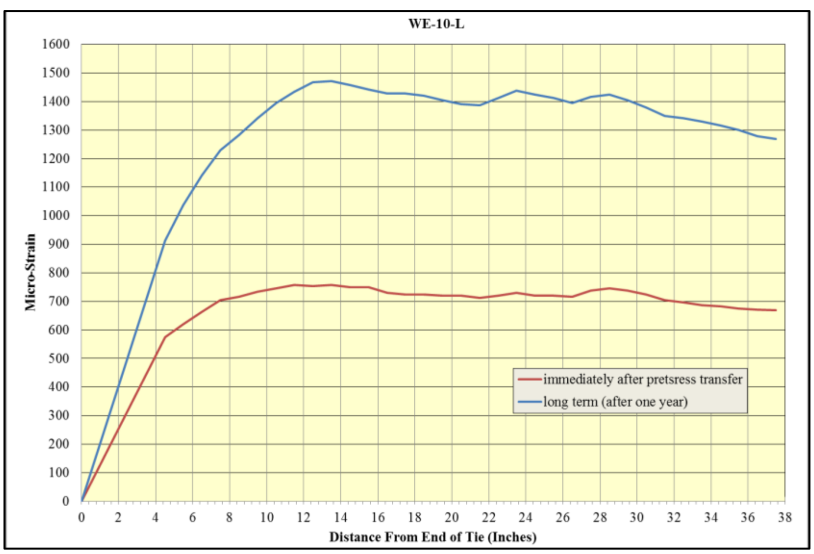


Figure 5: Typical Surface Strain Profile for ties stored at KSU (ex: WE-10-L)

Nomenclature

In order to best describe the transfer lengths results and strain increase corresponding to different combination of variables, a suitable nomenclature is chosen as shown in Figure 6. Through this nomenclature, results from different categories can be compared for the discussion. Also, results for ties stored at KSU and Plant can be separate out with the nomenclature provided in Figure 6 and can be better explained.

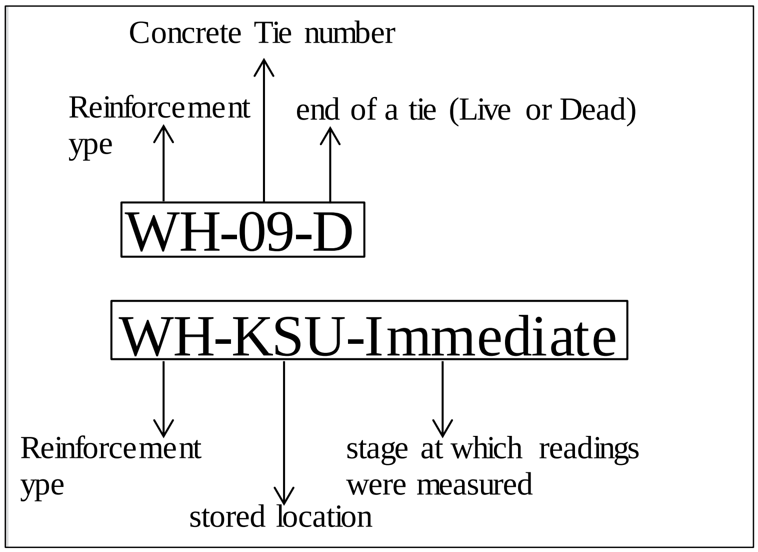


Figure 6: Nomenclature to identify the parameters

Variation of cross-section along the length of a concrete tie

A typical concrete tie is of 102-in. length with varying cross-section along its length as shown is Figure 7. This variation is symmetric about longitudinal center of the concrete tie. Cross-sectional properties along the length of the tie are measured using 3D Auto CAD software and tabulated in Table 1. Although, cross-sectional properties were determined at an interval of 0.5-in., due to space restrictions, Table 1 presents cross-sectional data at 5-in. interval. From Table 1, it can be observed the variation of the cross-section is appreciable over the length of a concrete tie.

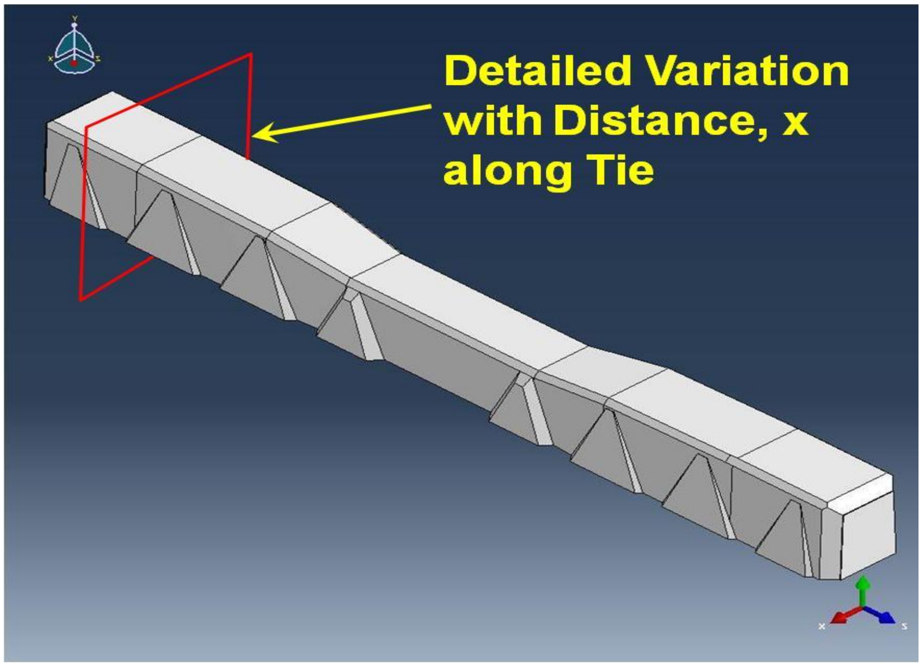


Figure 7: Typical Pretensioned concrete railroad tie

Table 1: Cross sectional properties along the length of a tie

distance from the end of the concrete tie (x, in.)	Total height (inch)	Cross-sectional area (in^2)	Distance between centroid and the bottom of the tie (inch)	y(top) (in)	Moment of Inertia about centroid (in^4)
0	8.20	55.26	4.03	4.17	209.61
5	9.54	93.54	4.59	4.95	701.85
10	9.54	88.89	4.68	4.86	645.72
15	9.49	92.63	4.55	4.94	688.25
20	9.36	89.56	4.50	4.87	658.67
25	9.24	87.50	4.45	4.78	627.61
30	9.03	88.21	4.32	4.71	589.52
35	8.20	69.44	4.02	4.18	384.87
40	7.54	73.59	3.56	3.97	332.26
45	7.54	59.50	3.70	3.84	278.44
50	7.54	59.50	3.70	3.84	278.44

Results and discussion

During the plant visit, a total of 60 pretensioned concrete railroad ties were fabricated at a PCI member plant with 15 different reinforcements that are used to manufacture concrete ties all over the world. Concrete properties for ties cast with each reinforcement type were measured and tabulated in Table 2. For each reinforcement type, eight transfer lengths were measured on four concrete ties at two stages (i.e. immediate and after one year). Two concrete ties for each reinforcement type are stored at plant and the remaining two ties are stored at KSU.

Transfer length results for "KSU-Immediate" ties

Average immediate transfer lengths for the ties stored at KSU are tabulated in Table 3 (column#2). It is to be noted that, each cell in Table 3 is the average of four transfer lengths. From Table 3, the average immediate transfer lengths for the ties stored at KSU and fabricate with 5.32-mm wires ranged from 4.9 in. to 13.5 in. This corresponds to a value of $23d_b$ to $64d_b$, where d_b is the diameter of the wire. In the case of 5.32-mm wire reinforcement, highest average transfer length (KSU-immediate) was observed in the case of smooth wire (i.e. no indentations), WA, and the value is 13.5-in. ($64d_b$)

The average transfer length (KSU-immediate) for chevron-shaped indented wires ranged from 5.8 in. (WH) to 7.9 in. (WI, WB), or $28d_b$ to $38d_b$. The average transfer length (KSU-immediate) of the Spiral-indented wires were 4.9 in. and 6.5 in., or $23d_b$ to $31d_b$ for WE and WC respectively. An average transfer length (KSU-immediate) of 9.5-in. or $45d_b$ was observed in the case of 2-dot indent pattern (minimal indentation). In the case of diamond pattern (WF), the average transfer length (KSU-immediate) is observed as 5.5-in. or $26d_b$.

The average transfer lengths (KSU-immediate) for the 7-wire 3/8"-diameter smooth (SA) and 7-wire 3/8"-diameter indented (SB) strands were 11.2 in. and 13.6 in. respectively. This corresponds to values of $30d_b$ and $36d_b$ respectively, which are significantly less than the assumption of $60d_b$ in current code equations[2]. Strand SA had some very minor surface rusting, whereas strand SB did not contain any visible rusting. Therefore, better performance was observed with the presence of surface rusting. The 3-wire 5/16"-diameter smooth strand (SC) had an average transfer length (KSU-immediate) of 11.2 in., which corresponds to $36d_b$.

Transfer length results for "Plant-Immediate" ties

Average immediate transfer lengths for the ties stored at plant are also tabulated in Table 3 (column#3). Average immediate transfer lengths for the ties stored at plant are very close to average immediate transfer lengths of the ties stored at KSU. This is mainly due to the fact that all concrete ties were cast at one time for any given type reinforcement. From Table 3, the average immediate transfer lengths for the ties stored at plant and fabricate with

5.32-mm wires ranged from 5.5 in. to 13.2 in. This corresponds to a value of $26d_b$ to $63d_b$. In the case of 5.32-mm wire reinforcement, highest average transfer length (plant-immediate) was observed in the case of smooth wire (i.e. no indentations), WA, and the value is 13.2-in. ($63d_b$).

The average transfer length (plant-immediate) for chevron-shaped indented wires ranged from 5.5 in. (WM) to 8.1 in. (WI), or $26d_b$ to $39d_b$. The average transfer length (plant-immediate) of the Spiral-indented wires were 6.1 in. to 6.9 in., or $29d_b$ to $33d_b$ for WE and WC respectively. An average transfer length (plant-immediate) of 8.3-in. or $40d_b$ was observed in the case of 2-dot indent pattern (minimal indentation). In the case of diamond pattern (WF), the average transfer length (plant-immediate) is observed as 5.7-in. or $27d_b$.

The average transfer lengths (plant-immediate) for the 7-wire 3/8"-diameter smooth (SA) and 7-wire 3/8"-diameter indented (SB) strands were 11.5 in. and 14.2 in. respectively. This corresponds to values of $31d_b$ and $38d_b$ respectively, which are also significantly less than the assumption of $60d_b$ in current code equations[2]. The 3-wire 5/16"-diameter smooth strand (SC) had an average transfer length (plant-immediate) of 11.0 in., which corresponds to $35d_b$.

Transfer length results for "KSU-long term" ties

Average long term transfer lengths for the ties stored at KSU are tabulated in Table 3 (column#4). From Table 3, the average long term transfer lengths for the ties stored at KSU and fabricate with 5.32-mm wires ranged from 7.1 in. to 15.6 in. This corresponds to a value of $34d_b$ to $74d_b$. Percentage growths in transfer lengths for different wire reinforcements are tabulated in Table 4. Figure 8 shows the comparison between average immediate and long term transfer lengths for the ties (cast with wire reinforcements) stored at KSU.

The average transfer length growths (ties stored at KSU) for chevron-shaped indented wires ranged from 12% (WB) to 31% (WG). The average transfer length growth (ties stored at KSU) of the Spiral-indented wires were 44% and 67% for WE and WC respectively. An average transfer length growth (ties stored at KSU) of 28% was observed in the case of 2-dot indent pattern (minimal indentation). In the case of diamond pattern (WF), the average transfer length growth (ties stored at KSU) is observed as 29%. Transfer length growth for the ties manufactured with WA and stored at KSU was 16%.

The average transfer lengths (KSU-long term) for the 7-wire 3/8"-diameter smooth (SA) and 7-wire 3/8"-diameter indented (SB) strands were 13.5 in. and 14.8 in. respectively (for a transfer length growth of 20% and 9%). This corresponds to values of $36d_b$ and $39d_b$ respectively, which are also less than the assumption of $60d_b$ in current code equations[2]. The 3-wire 5/16"-diameter smooth strand (SC) had an average transfer length (KSU-long term) of 12.5 in., which corresponds to $40d_b$ (for a transfer length growth of 12%). Percentage growths in transfer length for different strand reinforcements are tabulated in Table 4. Figure

9 shows the comparison between average immediate and long term transfer lengths for the ties (cast with strand reinforcements) stored at KSU.

Transfer length results for "Plant-long term" ties

Average long term transfer lengths for the ties stored at plant are tabulated in Table 3 (column#5). From Table 3, the average long term transfer lengths for the ties stored at plant and fabricate with 5.32-mm wires ranged from 6.6 in. to 17.6 in. This corresponds to a value of $32d_b$ to $84d_b$. Percentage growths in transfer lengths for different wire reinforcements are tabulated in Table 4. Figure 10 compares the average immediate and long term transfer lengths for the ties (cast with wire reinforcements) stored at plant.

The average transfer length growth (ties stored at plant) for chevron-shaped indented wires ranged from 19% (WI) to 29% (WG, WJ). The average transfer length growth (ties stored at plant) of the Spiral-indented wires were 36% and 76% for WE and WC respectively. An average transfer length growth (ties stored at plant) of 40% was observed in the case of 2-dot indent pattern (minimal indentation). In the case of diamond pattern (WF), the average transfer length growth (ties stored at plant) is observed as 28%. Transfer length growth for the ties manufactured with WA and stored at plant was 34%.

The average transfer lengths (plant-long term) for the 7-wire 3/8"-diameter smooth (SA) and 7-wire 3/8"-diameter indented (SB) strands were 17.4 in. and 17.2 in. respectively (for a transfer length growth of 51% and 21%). This corresponds to values of $46d_b$ and $46d_b$ respectively, which are also less than the assumption of $60d_b$ in current code equations[2]. The 3-wire 5/16"-diameter smooth strand (SC) had an average transfer length (plant-long term) of 14.4 in., which corresponds to $46d_b$ (for a transfer length growth of 31%). Percentage growths in transfer length for different strand reinforcements are tabulated in Table 4. Figure 11 compares the average immediate and long term transfer lengths for the ties (cast with strand reinforcements) stored at plant.

Transfer length growth: ties stored at plant vs ties stored at KSU

With the few exceptions, higher percentage of transfer length growth is observed for the ties stored at plant. Figure 12 and Figure 13 compares the percentage growth in transfer length for the ties stored at KSU with the ties stored at plant. The reason might be the difference in climatic conditions at two stored locations, as the remaining conditions stay constant for both storage locations.

Among all the reinforcements, highest transfer growth was observed for the ties manufactured with WC. These highest transfer length growths were 67% and 76% for the ties stored at KSU and Plant, respectively. For the ties stored at KSU, the lowest transfer length growth was 9% in the case of SB. Whereas, for the ties stored at plant, the lowest transfer length growth was observed in the case of WI which was 19%.

For the ties manufactured with WE, WI, and WM; higher transfer lengths were observed for the ties stored at KSU. Transfer length growth for the ties stored both at KSU and plant were approximately the same in the case of WF, WG, and WH. For the ties manufactured with the remaining reinforcements (9 reinforcements), higher transfer length growths were observed in the ties stored at plant.

Table 2: Concrete properties of ties fabricated with each reinforcement type

Description	Reinforcement Type	Wire/Strand Type	Release Strength (psi)	Split Tensile Strength (psi)
WA	Wire	Smooth	5365	672
WB	Wire	Chevron	6450	573
WC	Wire	Spiral	5617	520
WD	Wire	Chevron	5440	550
WE	Wire	Spiral	5277	618
WF	Wire	Diamond	5063	513
WG	Wire	Chevron	5440	550
WH	Wire	Chevron	5063	513
WI	Wire	Chevron	5217	515
WJ	Wire	Chevron	5447	598
WL	Wire	2-Dot	6600	554
WM	Wire	Chevron	6650	590
SA	Strand	Smooth	5277	618
SB	Strand	Indented	6600	554
SC	Strand	Smooth	5617	520

Table 3: Average transfer length measurements at various stages and at different tie storage locations

	KSU-Immediate	**Plant-Immediate**	**KSU-long term**	**Plant-long term**
Wire/ Strand Type	Avg. Transfer Length(TL), (in.) [TL/d_b]	Avg. Transfer Length(TL), (in.) [TL/d_b]	Avg. Transfer Length(TL), (in.) [TL/d_b]	Avg. Transfer Length(TL), (in.) [TL/d_b]
WA	13.5 [64]	13.2 [63]	15.6 [74]	17.6 [84]
WB	7.9 [38]	7.2 [34]	8.9 [42]	8.9 [43]
WC	6.5 [31]	6.9 [33]	10.8 [51]	12.1 [58]
WD	6.8 [32]	6.6 [31]	8.1 [39]	8.2 [39]
WE	4.9 [23]	6.1 [29]	7.1 [34]	8.3 [40]
WF	5.5 [26]	5.7 [27]	7.1 [34]	7.3 [35]
WG	7.2 [34]	7.9 [38]	9.4 [45]	10.1 [48]
WH	5.8 [28]	5.8 [28]	7.3 [35]	7.2 [34]
WI	7.9 [38]	8.1 [39]	10.2 [49]	9.6 [46]
WJ	6.1 [29]	6.1 [29]	7.3 [35]	7.9 [37]
WL	9.5 [45]	8.3 [40]	12.2 [58]	11.7 [56]
WM	6.2 [29]	5.5 [26]	7.6 [36]	6.6 [32]
SA	11.2 [30]	11.5 [31]	13.5 [36]	17.4 [46]
SB	13.6 [36]	14.2 [38]	14.8 [39]	17.2 [46]
SC	11.2 [36]	11.0 [35]	12.5 [40]	14.4 [46]

Table 4: Transfer length growths in percentages: plant vs KSU

Wire/Strand Type	Percentage increase in transfer lengths for ties stored at KSU	Percentage increase in transfer lengths for ties stored at Plant
WA	16%	34%
WB	12%	24%
WC	67%	76%
WD	20%	24%
WE	44%	36%
WF	29%	28%
WG	31%	29%
WH	26%	25%
WI	29%	19%
WJ	19%	29%
WL	28%	40%
WM	23%	20%
SA	20%	51%
SB	9%	21%
SC	12%	31%

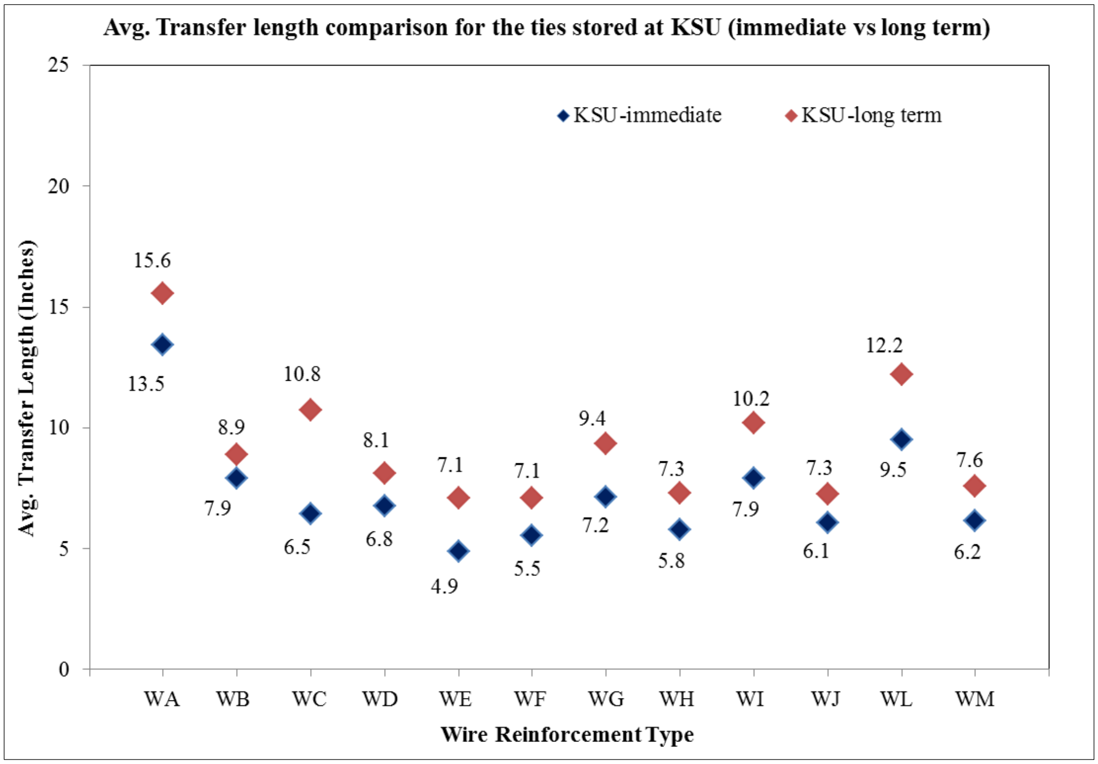


Figure 8: Long term vs Immediate transfer lengths for wires (stored at KSU)

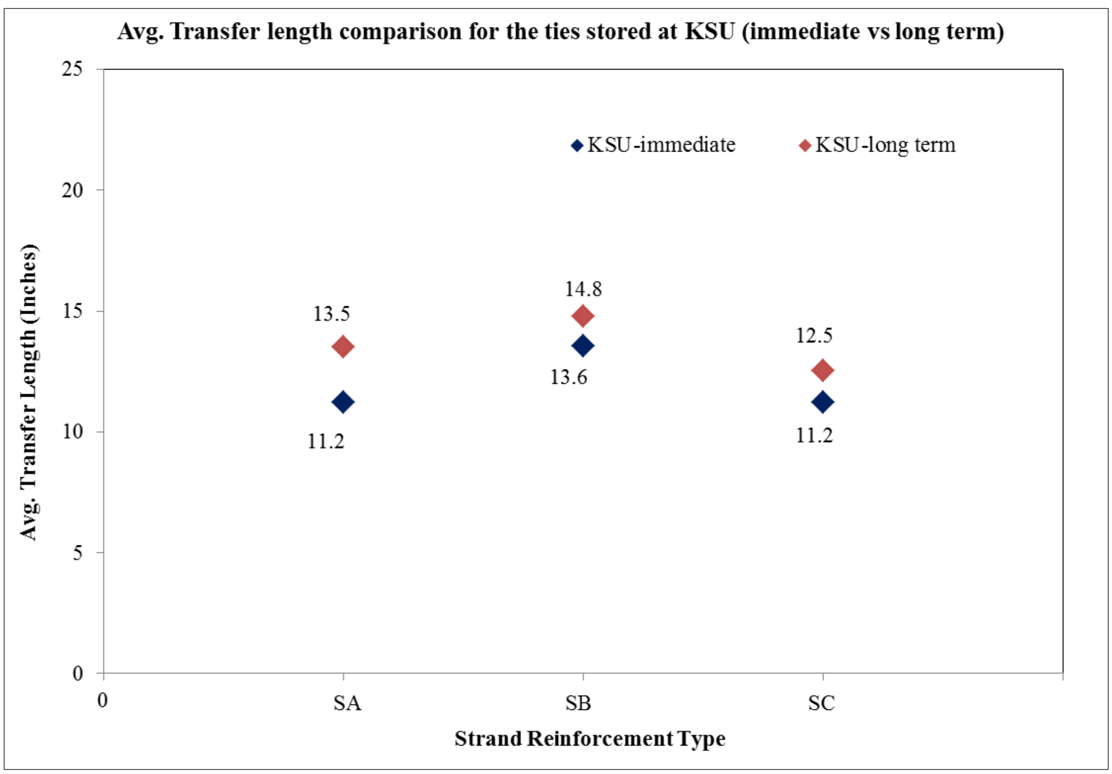


Figure 9: Long term vs Immediate transfer lengths for strands (stored at KSU)

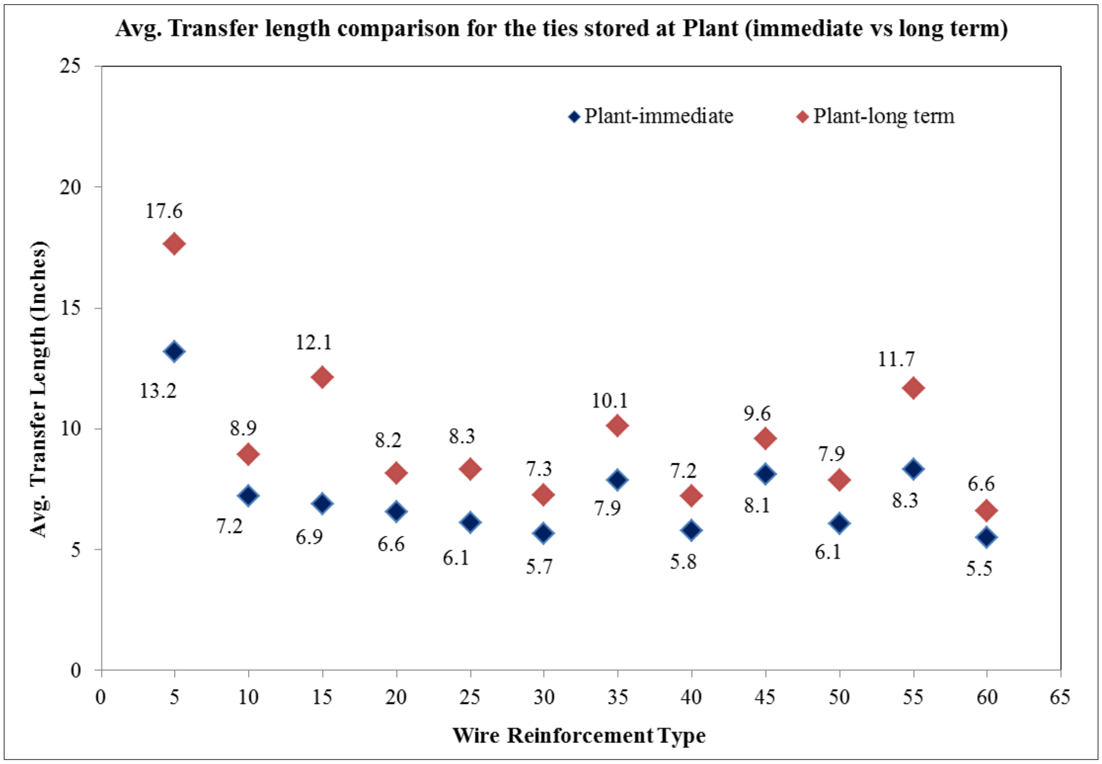


Figure 10: Long term vs Immediate transfer lengths for wires (stored at plant)

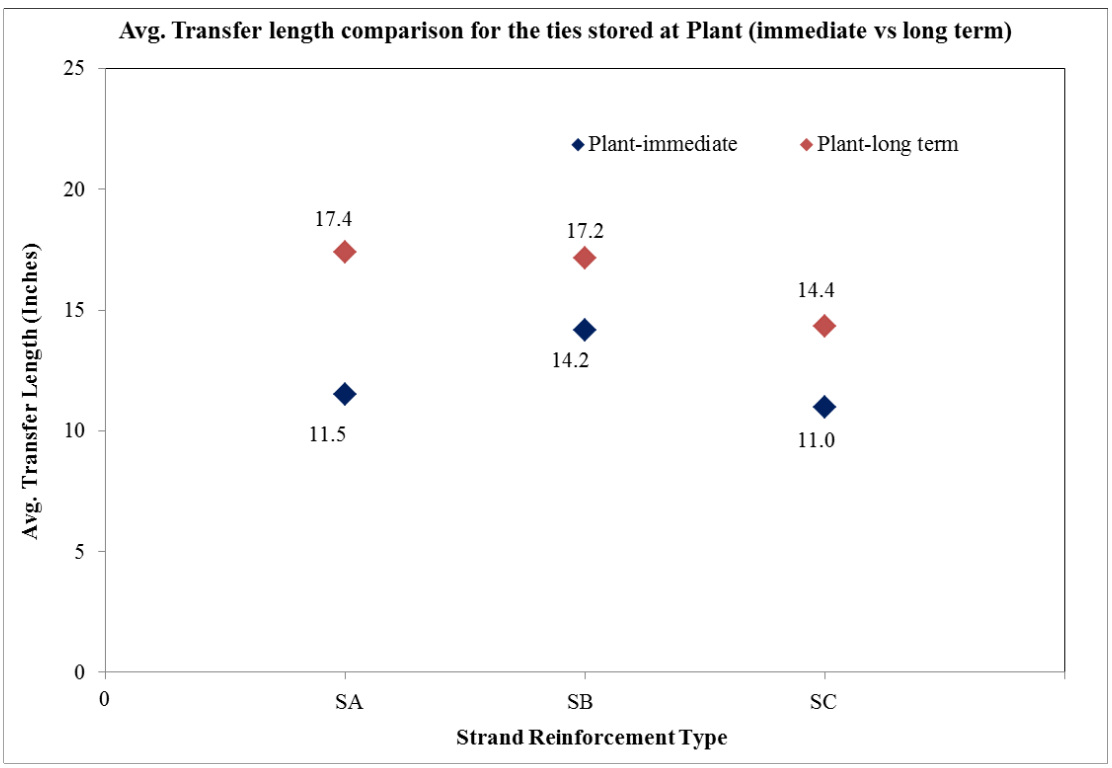


Figure 11: Long term vs Immediate transfer lengths for strands (stored at plant)

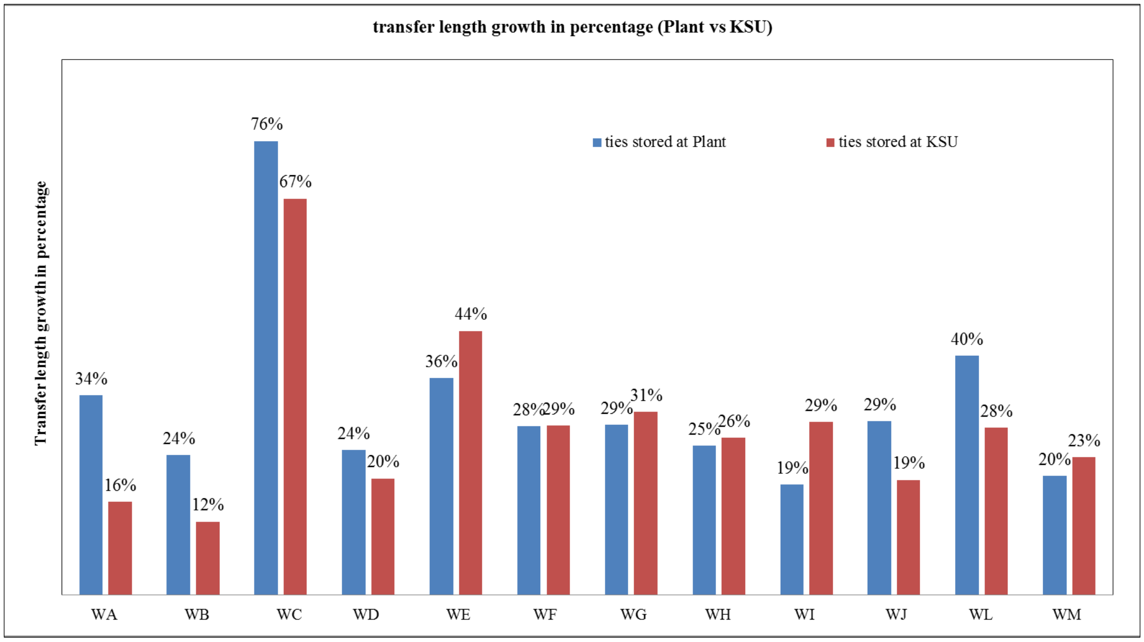


Figure 12: Transfer length growth in percentages-wires : plant vs KSU

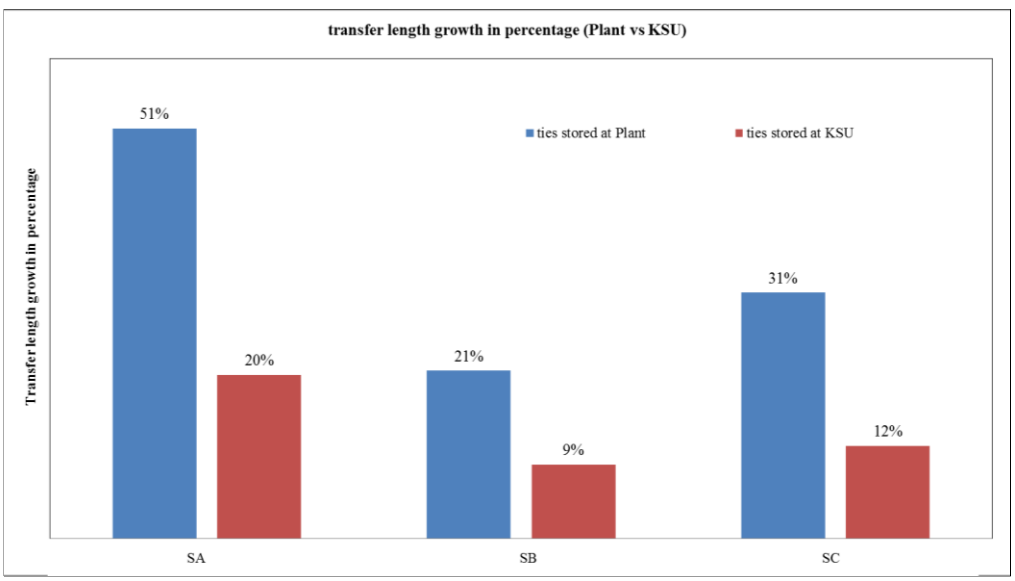


Figure 13: Transfer length growth in percentages-strands : plant vs KSU

Strain increment due to creep

Due to sustained prestressed force on these concrete ties, strain growths were observed due to creep. Strain increment varied based on the storage location (plant vs KSU) and also it varied along the length of the concrete tie. Table 5 presents the overall increment in strains for ties fabricated with 15 different reinforcements and stored at different locations. Higher strain increments were observed for the ties stored at plant.

However, percentage increase in strain for a given tie is not constant along the length of the tie. It is observed that the strain increase in varied along the length of the tie and followed a constant trend for all specimens. A typical surface strain increase in surface strain along the length of the tie is shown in Figure 14.

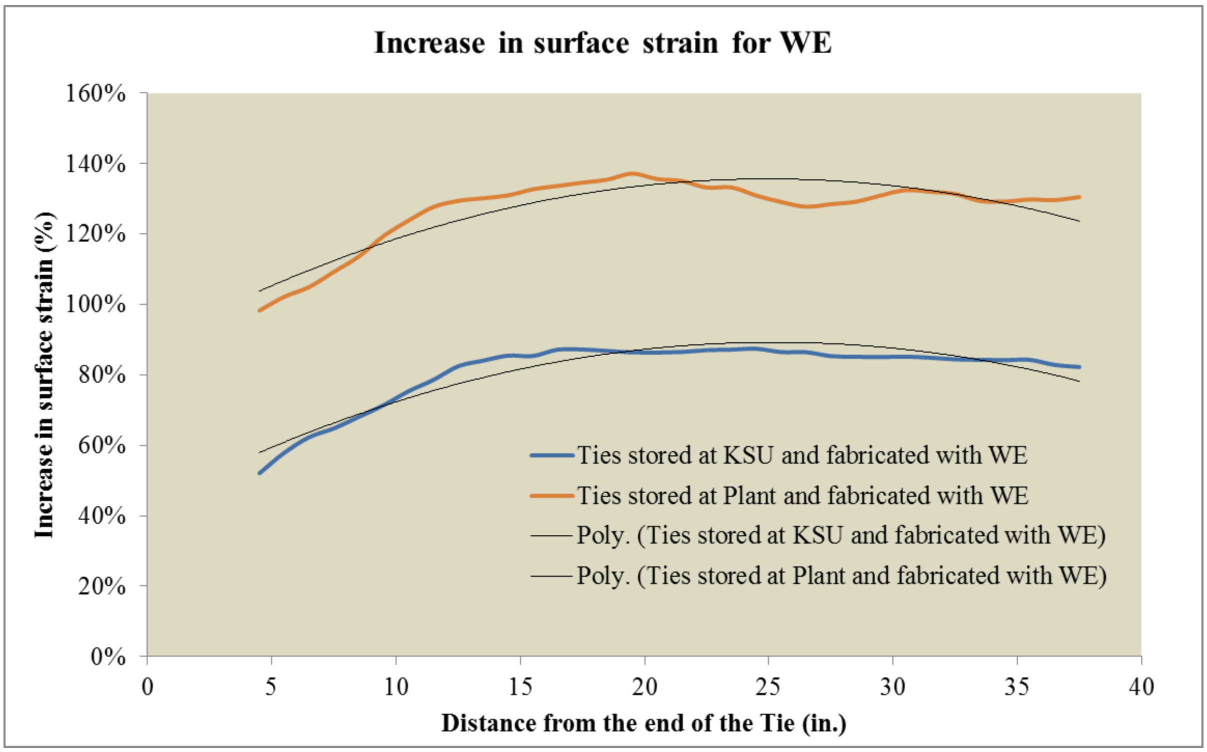


Figure 14: Typical variation of strain increase along the length of a tie

Table 5: Average strain increment in ties cast with for various reinforcements (stored at plant vs stored at KSU)

Reinforcement Type	storage location	% increase in strain	difference in % strain increase between plant and KSU
WA	plant	92%	12%
	KSU	80%	
WB	plant	106%	19%
	KSU	87%	
WC	plant	113%	36%
	KSU	77%	
WD	plant	122%	25%
	KSU	97%	
WE	plant	127%	46%
	KSU	81%	
WF	plant	124%	39%
	KSU	85%	
WG	plant	126%	26%
	KSU	100%	
WH	plant	124%	23%
	KSU	101%	
WI	plant	105%	7%
	KSU	98%	
WJ	plant	134%	25%
	KSU	109%	
WL	plant	105%	27%
	KSU	78%	
WM	plant	142%	32%
	KSU	111%	
SA	plant	118%	46%
	KSU	71%	
SB	plant	121%	24%
	KSU	96%	
SC	plant	120%	36%
	KSU	85%	

Conclusions

Based on the present study, following conclusions can be drawn

1. Transfer length growth in a pretensioned concrete member is essential, however the growth varies depends on the climatic conditions and type of reinforcement.
2. For ties stored at plant experienced more growth in transfer length compared to ties stored at KSU (with the exception of few reinforcements) for the given period of time.
3. For the ties stored at plant, transfer lengths growth are observed as high as 76% in the case of ties with WC and as low as 19% in the case of WI and WJ.
4. For the ties stored at KSU, transfer lengths growth are observed as high as 67% in the case of ties with WC and as low as 9% in the case of SB.
5. Increase in strain is observed due to creep and is also not constant along the length of the tie. Higher stain increases are observed for ties stored at plant
6. Strain increase along the length of the tie is observed to follow trend for all reinforcements and is observed to be inversely proportional to the cross sectional area of a tie.

Recommendations and further research

From the essential information obtained in the present study, it is recommended to consider the transfer length growth in the design of pretensioned concrete railroad tie. In a concrete rail road tie, strain increase over a period of time can be lowered by increasing cross-sectional dimensions. Results from the present study indicated that strain growth varies due to environmental conditions. Hence, during the design of pretensioned concrete members transfer length needs to be estimated by considering environmental conditions. It is also recommended to estimate the transfer length growth depending on the prestressing reinforcement used in a pretensioned concrete member.

Transfer length results presented in this paper were obtained on concrete rail road ties without subjected to any rail loads. Hence, transfer length variation due to the application road loads is essentially unknown. Therefore, it is recommended to measure the transfer lengths after the application of rail loads on these concrete rail road ties. These transfer length measurements will provide more insight of a concrete rail road tie under loading conditions.

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